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⑤④ Two-part self-indicating adhesive composition.

⑤⑦ An adhesive composition which exhibits fast curing through large gaps is disclosed. The composition comprises (A) at least one addition polymerizable vinyl-type monomer; (B) at least one free radical stabilizer; and (C) a free radical cure system. The free radical cure system comprises (i) at least one free radical initiator, and (ii) at least one ferrocene type compound.

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This invention relates to an adhesive composition of the type which exhibits fast curing through large gaps on inactive substrates (substrates not involved in the adhesive cure mechanism) following a controllable induction time. It relates more particularly to a two-component adhesive composition which is applied as a one-part adhesive, when the two components have been mixed.

A major disadvantage of prior art two-part mixed adhesive compositions that are room temperature-curing is that fast curing inevitably means a short pot life and problems with mixing equipment. This problem of a short pot life is conventionally solved by adding an inhibitor to the polymerization system. The inhibitor then reacts with the active species of the catalyst-activator system thus stopping polymerization until the inhibitor is consumed. The larger the amount of inhibitor the longer is the induction period and the smaller the amount of catalyst available at the end of the induction period. As the rate of polymerization is usually a function of the catalyst concentration a long induction period may result in slow and incomplete cure.

Another disadvantage of the said prior art compositions is that a mixture of the two components is difficult to distinguish from either of the components before mixing. It is known to incorporate a first dye in one component, and a second dye in the other component, so that the mixture of the components has a color other than that of either of the dyes. This however is an undesirable complication of the work of manufacturing such compositions.

A further disadvantage is that the mixture, once applied to a pair of substrates which are then placed or cramped in mutual contact, although visible at the edges of the joint, and more fully visible through a substrate

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if the latter is transparent, gives no visible inkling of its state of cure.

It is an object of the present invention to provide an adhesive composition in which a controllable induction period is followed by rapid polymerization giving complete cure through very large gaps. Another object of the invention is to provide a two-part adhesive composition wherein mixing of the parts produces a color change, enabling the mixture to be instantly recognized as such, and providing a visible reminder of its limited pot life. A further object is to provide an adhesive composition wherein cure is accompanied by a color change.

In accordance with the invention there is provided an adhesive composition of the type which exhibits fast curing through large gaps on inactive substrates following a controllable induction time, which composition comprises

- (i) at least one addition polymerizable vinyl-type monomer as hereinafter defined;
- (ii) a cure system comprising a free radical initiator and at least one accelerator therefor, namely a ferrocene type compound; and
- (iii) at least one free radical stabilizer of the quenching type.

The composition may additionally comprise polymeric additives(s), dye(s), pigments(s) or filler(s).

The invention will now be described, by way of example, with reference to the accompanying drawings in which:

Figure 1 is a series of exotherms plotted as temperature in °C versus time in minutes showing the effect of varying stabilizer levels;

Figure 2 is a series of exotherms plotted as

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temperature in °C versus time in minutes showing the effect of varying initiator levels; and

Figure 3 is a series of exotherms plotted in °C versus time in minutes showing the effect of varying accelerator levels.

5 The addition polymerizable monomers are preferably selected from the group that consists of monofunctional acrylate or methacrylate esters, diacrylate or dimethacrylate esters, urethane acrylate or urethane methacrylate compounds, and other unsaturated reactive comonomers.

10 Examples of these monomers (i) are Methyl methacrylate, Butyl methacrylate, Tetrahydrofurfuryl methacrylate, Cyclohexyl methacrylate and the reactive monomers described in U.S. Patents 3,425,988 to Toback and Gorman and 4,018,851 to Baccei.

The cure system (ii) typically comprises a free radical initiator and a combination of free radical accelerators one of which is a ferrocene type compound.

20 Examples of these initiators are Benzoyl peroxide, p-Chlorobenzoyl peroxide, o-Methyl benzoyl peroxide and Lauroyl peroxide.

Examples of ferrocene type compounds are Ferrocene, t-Butyl ferrocene, t-Octyl ferrocene and Vinyl ferrocene.

25 Preferred accelerators other than ferrocene type compounds are tertiary aromatic amines, such as N,N-Dimethylaniline, N,N-Diethyl-p-toluidine and N,N-Dihydroxyethyl-p-toluidine.

30 Cure systems of the kind described are capable of producing a surface independent non-anaerobic cure.

The free radical stabilizer is of the quenching type. Examples of these stabilizers are Hydroquinone, 2,6-di-t-Butyl-4-methylphenol and 4-Methoxyphenol.

35 The invention will be understood in greater detail from the accompanying drawings and the following examples:

Example 1:

Adhesive compositions were prepared using the following ingredients:

(i) Monomers:

- 5 (1) Tetrahydrofurfuryl methacrylate
 (2) Methacrylic acid
 (3) 1,3-Butylene glycol dimethacrylate

(ii) Cure System:

- 10 (4) Benzoyl Peroxide (initiator)
 (5) Ferrocene (accelerator)
 (6) N,N-Dihydroxyethyl-p-toluidine (accelerator)

(iii) Stabilizer:

- (7) 2,6-di-t-Butyl-4-methylphenol

(iv) Polymeric Additives:

- 15 (8) Ethylene methyl acrylate copolymer.

In formulating useful two-part compositions from these ingredients, ingredient 4 must be kept apart from ingredients 5 and 6 by separate packaging or other means well known in the art.

- 20 A stock solution was made up according to the following recipe, in which the ingredients are designated by the respective numbers given above. The quantities are to be understood as parts by weight totalling 100.

25 Stock Solution

	<u>Quantities</u>
(1) Tetrahydrofurfuryl methacrylate(i)	58.85
(2) Methacrylic acid	10.42
(3) 1,3-Butylene glycol dimethacrylate(i)	2.08
30 (8) Ethylene methyl acrylate copolymer(iv)	28.65

Total 100.00

Two-part adhesive compositions were then made up using this stock solution and ingredients 4-7 the proportions of which were as follows:

Part 1. Quantities

5	(4) Benzoyl peroxide (ii)	1.0
	(7) 2,6-di-t-Butyl-4-methoxyphenol (iii)	0.1
	Stock Solution sufficient to add up to	100.0

Part 2. Quantities

10	(5) Ferrocene	0.2
	(6) N,N-Dihydroxyethyl-p-toluidine	1.0
	Stock Solution sufficient to add up to	100.0

On mixing Part 1, which was yellow, with Part 2, which was orange, a green solution was obtained and an

15 induction time began. Following this induction period there was a period of rapid polymerization producing a hard yellow polymer. These color changes are of course of great utility to the user; the composition may be termed self-indicating by virtue of them.

20 Example 2:

Represented in Figures 1-3 are polymerization exotherms recorded with a thermocouple recorder unit and plotted as temperature in °C versus time in minutes.

Figure 1 shows how the induction time may be varied by changing the proportion of the 2,6-di-t-Butyl-4-methylphenol stabilizer in the composition of Example from 0.050 wt. % (line I), 0.075 wt. % (line II), to 0.100 wt. % (line III).

Figure 2 shows that this effect also may be achieved by varying the proportion of the benzoyl peroxide initiator from 0.75 wt. % (line I), 1.00 wt. % (line II), to 1.50 wt. % (line III); and Figure 3 shows that this effect also may be achieved by varying the proportions of the ferrocene and

35 N,N-Dihydroxyethyl-p-toluidine in the accelerator

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system, respectively, in the composition, in accordance with the following (all parts are parts by weight):

<u>Line No.</u>	<u>Accelerator System</u>	
5	<u>Ferrocene</u>	<u>N,N-Dihydroxy-ethyl-p-toluidine</u>
	I	0.40% 1.50%
	II	0.40% 1.00%
10	III	0.20% 1.50%
	IV	0.20% 1.00%

Example 3:

A two-part adhesive composition was made up according to the following recipe. The quantities are to be understood as parts by weight. Each part of this composition adds up to 100.

	<u>Part 1. Quantities</u>
(1) Tetrahydrofurfuryl methacrylate (i)	43.00
(2) Methacrylic acid (i)	10.00
20 (3) 1,3-Butylene glycol dimethacrylate (i)	2.00
(4) Benzoyl peroxide (ii)	1.25
(7) 2,6-di-t-Butyl-4-methyl phenol (iii)	0.125
(8) Ethylene methyl acrylate copolymer (iv)	22.125
Methyl methacrylate butyl methacrylate	
25 copolymer (iv)	20.00
Silicon dioxide (iv)	1.50

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Part 2. Quantities

	(1) Tetrahydrofurfuryl methacrylate (i)	43.00
	(2) Methacrylic acid (i)	10.00
	(3) 1,3-Butylene glycol dimethacrylate (i)	2.00
5	(5) Ferrocene (ii)	0.25
	(6) N,N-Dihydroxyethyl-p-toluidine (ii)	1.00
	(7) 2,6-di-t-Butyl-4-methyl phenol (iii)	0.15
	(8) Ethylene methyl acrylate copolymer (iv)	22.10
	Methyl methacrylate butyl methacrylate	
	copolymer (iv)	20.00
10	Silicon dioxide (iv)	1.50

For use, equal weights of the two parts were intimately mixed and the mixture applied to a 2.54 x 1.27cm area on each of a pair of 2.54cm wide abraded gel coat glass-reinforced plastics strip substrates. The treated areas were placed in contact and clamped together. Uniform bond gaps of 4mm were achieved with the use of glass spacers. The bonds were allowed to set.

A number of such bonds was allowed to stand at room temperature for 24 hours to develop full cure. They were then tested to destruction according to ASTM D1002-64 to determine their tensile shear strength in decaNewtons per square centimeter (daNcm^{-2}). The mean result recorded was 23 daNcm^{-2} with substrate failure being observed in each case.

Thus the ultimate strengths recorded were determined by the cohesive strength of the substrate which was less than the forces of adhesion operating.

An induction time of 30 minutes was recorded for the assembled adhesive using both the polymerization exotherm and color change as indicators.

CLAIMS

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1. An adhesive composition comprising:
 - (A) at least one addition polymerizable vinyl-type monomer;
 - (B) at least one free radical stabilizer; and
 - (C) a free radical cure system;
- 5 characterized in that said free radical cure system comprises (i) at least one free radical initiator, and (ii) at least one ferrocene type compound.
2. The adhesive composition of claim 1,
- 10 characterized in that said polymerizable monomer is selected from monofunctional acrylate and methacrylate esters, diacrylate and dimethacrylate esters, and urethane acrylate and urethane methacrylate compounds.
3. The adhesive composition of claim 1 or claim 2,
- 15 characterized in that said free radical polymerizable initiator comprises an organic peroxide compound, preferably benzoyl peroxide, p-chlorobenzoyl peroxide, o-methylbenzoyl peroxide or lauroyl peroxide.
4. The adhesive composition of any of claims 1 to 3, characterized in that said ferrocene type compound is
- 20 selected from ferrocene, t-butyl ferrocene, t-octyl ferrocene and vinyl ferrocene.
5. The adhesive composition of any of claims 1 to 4, characterized in that said free radical stabilizer is
- 25 selected from hydroquinone, 2,4-di-t-butyl-methylphenol and 4-methoxyphenol.
6. The adhesive composition of any of claims 1 to 5, characterized by comprising a two part composition in which said ferrocene type compound is isolated from said
- 30 free radical initiator prior to use.
7. A cure system for an addition polymerizable vinyl-monomer characterized by comprising at least one free radical initiator, and a combination of free radical accelerators, at least one of which is a
- 35 ferrocene type compound, wherein said ferrocene type

compound and said other free radical accelerators are kept apart from one another prior to use.

8. A two part adhesive composition characterized by comprising:

5 (A) a first part which comprises (i) at least one addition polymerizable vinyl-type monomer, (ii) a free radical initiator, and (iii) a free radical stablizer; and

10 (B) a second part which comprises (i) at least one addition polymerizable vinyl-type monomer, (ii) a ferrocene type compound; and (iii) at least one free radical stabilizer.

9. The adhesive composition of claim 8, characterized by one or more of the following features:

15 (a) said polymerizable monomer is selected from monofunctional acrylate and methacrylate esters, diacrylate and dimethacrylate esters, and urethane acrylate and urethane methacrylate compounds;

20 (b) said free radical polymerizable initiator comprises an organic peroxide compound, preferably benzoyl peroxide, p-chlorobenzoyl peroxide, o-methylbenzoyl peroxide or lauroyl peroxide;

25 (c) said ferrocene type compound is selected from ferrocene, t-butyl ferrocene, t-octyl ferrocene and vinyl ferrocene; and

(d) said free radical stabilizer is selected from hydroquinone, 2,4-di-t-butyl-methylphenol and 4-methoxyphenol.

30 10. A method of bonding surfaces together, characterized by the steps in sequence of:

(1) providing a two-part polymerizable adhesive composition which comprises (A) a first part comprising (i) at least one addition polymerizable vinyl-type monomer, (ii) at least one free radical initiator, and 35 (iii) at least one free radical stabilizer; and (B) a

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second part comprising a ferrocene-type polymerization accelerator;

(2) blending said first and second parts to form a substantially homogeneous mixture of said parts;

5 (3) applying the mixture from step (2) to one or both surfaces to be bonded; and

(4) placing said surfaces under abutting relationship under conditions to promote curing of said adhesive composition.

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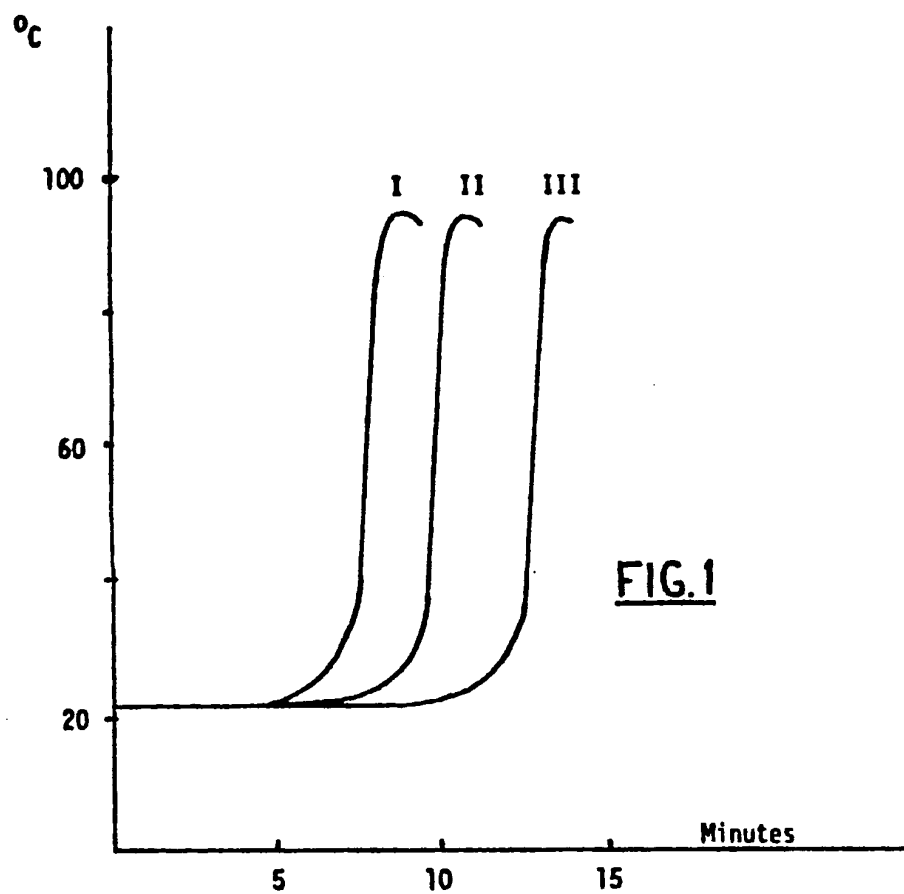
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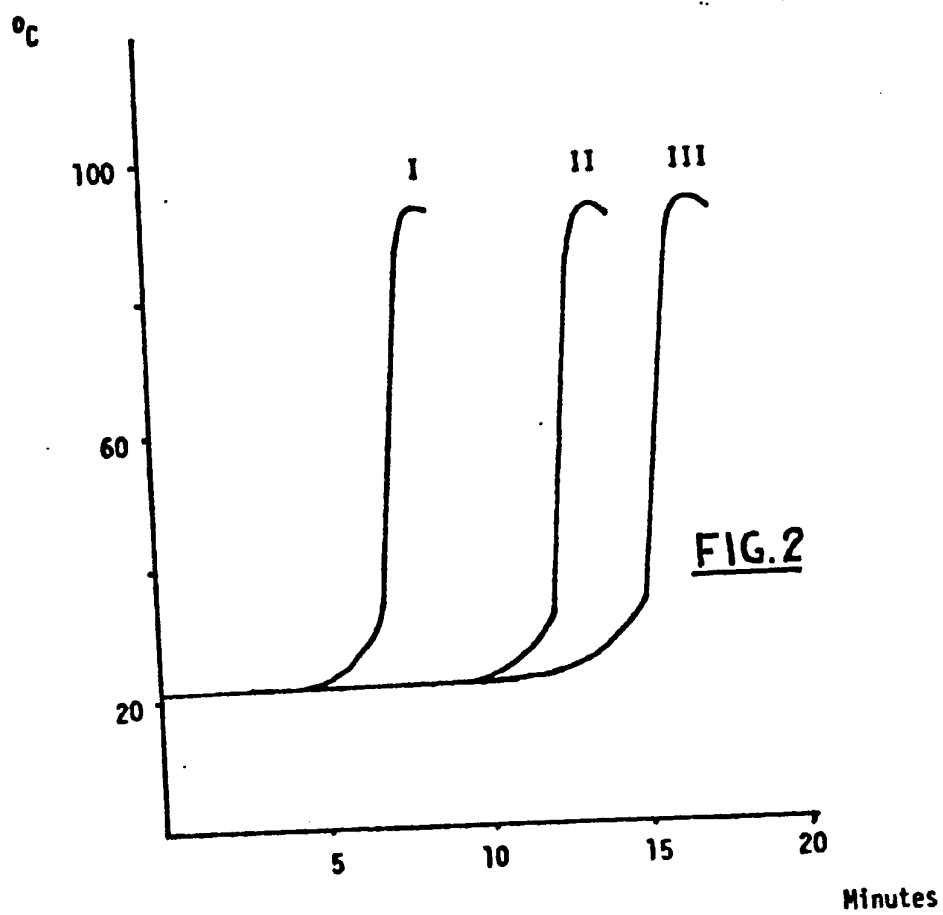
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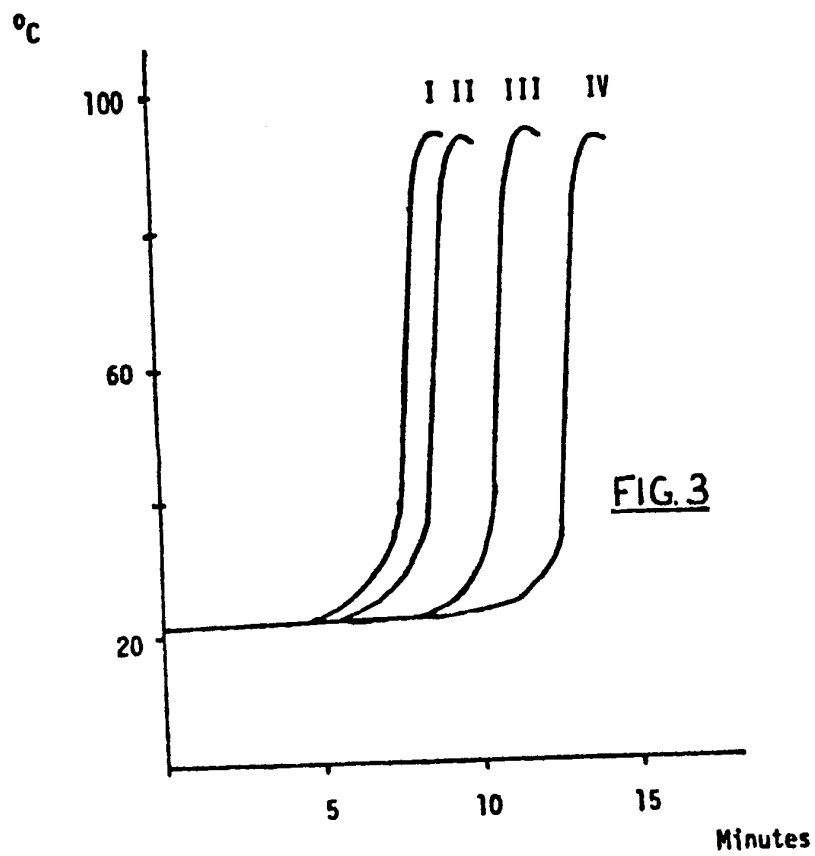
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EUROPEAN SEARCH REPORT

0096500
Application number

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DOCUMENTS CONSIDERED TO BE RELEVANT			Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 7)
Category	Citation of document with indication, where appropriate, of relevant passages			
X	US - A - 3 855 040 (B.M. MALOFSKY) * Column 2, lines 11-44, lines 55-59; column 3, line 11 - column 4, line 62; column 6, lines 4-21; column 8, lines 61-68; column 9, lines 1-12; claims 1-4,8,16 *	1-10	C 09 J 3/00 C 08 K 5/56 C 09 J 5/00	
P,X	DE - A1 - 3 217 658 (LOCTITE) * Page 18, lines 21-31; page 19, lines 1-25; claims 1,3,4, 7,9,14-16 *	1-10		
A	DE - A - 1 901 919 (WALLACE & TIERNAN CHEMIE) * Claims 1-3; table I,V *	1,3,4, 8		
The present search report has been drawn up for all claims			TECHNICAL FIELDS SEARCHED (Int. Cl. 7)	
			C 09 J C 08 L C 08 J C 08 F C 08 K	
Place of search VIENNA		Date of completion of the search 31-08-1983	Examiner KAHOVEC	
CATEGORY OF CITED DOCUMENTS				
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document		

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